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1501 Foshay Tower, 821 Marquette Ave., Minneapolis, 2, Minn.

ANNUAL SUBSCRIPTION $4.00 CANADA $4.50, FOREIGN $5.00
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Publication Office: 1501-04 Foshay Tower, 821 Marquette Av., Minneapolis 2, Minn

AMERICAN JOURNAL OF OPTOMETRY *and* ARCHIVES *of* AMERICAN ACADEMY OF OPTOMETRY

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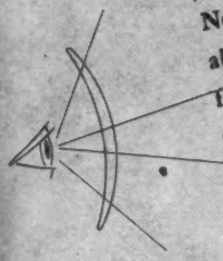

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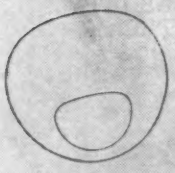

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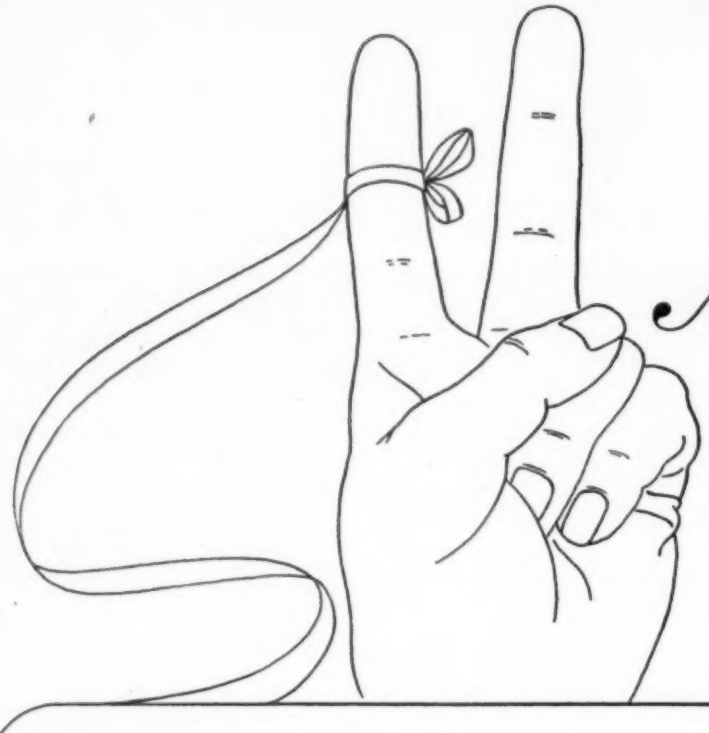

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Vol. 21 JANUARY, 1944 No. 1

FACTS OF COLOR-BLINDNESS*

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1. EARLY HISTORY

Color-blindness is a subject requiring statistical treatment; there are types of color-blindness and a greater or lesser adherence of groups of observers to these types. These facts are disclosed in a literature which is sufficiently extensive itself to require statistical treatment. Figure 1 shows the distribution of titles according to decade for a fairly complete bibliography on color-blindness. To present some semblance of historical perspective, it is convenient to summarize the discoveries about color-blindness up to 1885 before attempting a summary of present-day knowledge.

According to this bibliography there appeared in 1684 in the *Philosophical Transactions of the Royal Society* an account by D. Tuberville of "Several Remarkable Cases in Physick Relating Chiefly to the Eyes."[51] This is perhaps the first published indication that there is such an abnormality as color-blindness. Ninety-three years later the indication is definite. J. Huddart published in the same transactions (1777) an account "Of a Person Which Could Not Distinguish Colours,"[18] and Whisson in 1778 published "An Account of a Remarkable Imperfection of Sight."[57]

However, not until Dalton's account of his own case appeared in 1798 in the *Memoirs of the Literary and Philosophical Society of Manchester*[2] could it be said that a lucid description of color-blindness had been given. Dalton said of the spectrum (p. 31), "I found that persons in general distinguish six kinds of colour in the solar image, namely, red, orange, yellow, green, blue, and purple. Newton, indeed, divides the

*Paper presented at the Symposium on Color-Blindness at the meeting of the Optical Society of America, New York, March 5-6, 1943. From the Journal of the Optical Society of America. Vol. 33, No. 6, 1943. Page 294.

purple in indigo and violet; but the difference between him and others is merely nominal. To me it is quite otherwise. I see only two, or at most three, distinctions. These I should call yellow and blue, or yellow, blue and purple. My yellow comprehends the red, orange, yellow, and green of others; and my blue and purple coincide with theirs." And elsewhere (p. 34), "Woolen yarn, dyed crimson, or dark blue is the same to me."

Dalton's explanation for his abnormal vision was that his eye media must absorb the red end of the spectrum strongly and so prevent him from seeing as others did. In commenting on this explanation, Thomas Young[61] said, " . . . it is much more simple to suppose the absence or paralysis of those fibers of the retina which are calculated to perceive red." This is the original statement of the Young theory of color-blindness, which has probably attracted more attention than any other explanation and exerts a profound influence today.

The question was immediately raised whether Dalton was really blind to the extreme red end of the spectrum and Herschel (p. 60),[58] after experimenting with Dalton as a subject told him, "It is clear to me that you, and all others so affected, perceive *as light* every ray which others do. . . . It seems to me that we (the normal-eyed) have three primary sensations where you have only two. We refer or can refer in imagination all colours to three, . . . All other colours we think we perceive to be mixtures of these, and can produce them by actual mixtures of powders of the primary hues, . . . Now, to eyes of your kind, it seems to me that all your tints are referable to two." However, Dalton persisted in his own explanation, and was not proven to be wrong until after his death in 1844 when posthumous examination of his eye media showed them to be normally transparent for red light (p. 54).[58]

Color-blindness aroused much interest during the early part of the nineteenth century, and was called Daltonism by European writers of those times over the protests of British scientists, who thought Dalton should be known as the originator of the atomic theory of matter rather than the arch-type of a defect of vision. A continuing controversy raged concerning whether color-blind observers are really blind to red. The answer was given by Seebeck[48] in 1837 that some color-blinds are relatively insensitive to red, but most are not.

In 1852 Helmholtz[13] gave an account of compound colors on the basis of the Young theory, and in 1855 Maxwell[31] pointed out that according to this theory it is possible to define the confusion colors of color-blinds in terms of the color triangle now known as the Maxwell

triangle. He said, "If we find two combinations of colours which appear identical to a color-blind person, and mark their positions on the triangle of colours, then the straight line passing through these points will pass through all points corresponding to other colours, which, to such a person, appear identical with the first two."

Thus, within 60 years of Dalton's description of color-blindness many of the chief questions had been raised and answered correctly. Color-blindness was found to have a number of forms, chief of which correspond to a reduction from the normal three-component visual system to a two-component system as in Dalton's case of partial color-blindness,

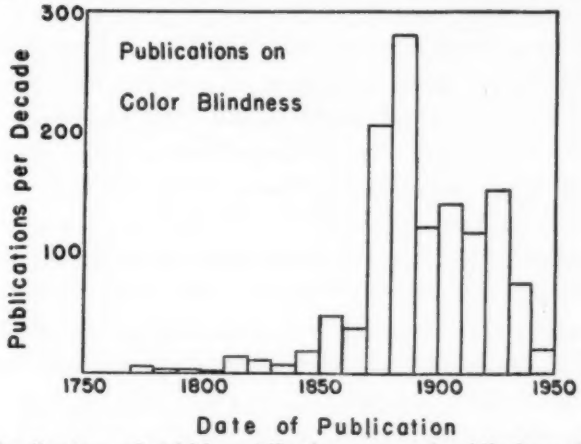

Fig. 1. Distribution of 1200 publications on color-blindness by decade. Note the great activity between 1870 and 1890, and the continuing steady interest since that time.

or to a one-component system as in cases of total color-blindness. The chief characteristic of color-blindness, that of chromaticity confusion, was recognized and Maxwell had pointed out how these confusions could be represented accurately on the Maxwell triangle. Furthermore, Dalton had correctly analyzed his own sensations as yellow and blue. It was known that there are degrees of chromaticity confusion as well as different kinds. Permanent or inherited color-blindness was found in some degree or other in about 10 per cent of the male population, and in a considerably smaller fraction of the female population. Cases of color-blindness associated with injury and disease had also been established.

Thus in 1855 it would have been possible for a clairvoyant to make an outline of the chief facts of color-blindness from the then existing literature. But there was considerable contradictory evidence and many conclusions drawn from faulty or insufficient ground. Thus, because of

lack of photometric equipment, Herschel failed to establish that Dalton was less than normally sensitive to the long-wave end of the spectrum in spite of the fact that both Young's explanation and Dalton's own explanation required it. It had been correctly pointed out that, in spite of a proven connection between color vision and the pigmentation of the eye media, the color of eyes and hair is no reliable guide to color-blindness; but the question was still open whether color-blind observers could be detected by a flatness of the skull just beneath the eyebrows. One eminent British authority prescribed test methods foreshadowing the Holmgren wool test, but also suggested (p. 152)[58] that the detection of color-blind observers might also be assisted by "a singular expression of their eyes, either a startled expression as if they were alarmed" or "an aimless eager glance, as if seeking to perceive something but unable to find it." This point was raised again in 1881.[19] Almost the first theory of color-blindness, the Young theory, still commands respect, but there were other theories to choose from, the eye-pigment theory, the choroid-coat coloration theory, and various phrenological theories, none at all elaborated so as to be amenable to check. Thus we may say that in 1855 the important questions about color-blindness had been raised and qualitatively correct answers had been supplied, but the qualitative facts had not been proven, they had merely been suggested; and of the quantitative facts almost none had been established.

The year 1855 is a convenient one for taking stock not only because the ground-work had been laid by Helmholtz and Maxwell for the evaluation of the precise properties of color-blind vision, but also because the importance of excluding color-blind observers from certain occupations was beginning to be generally recognized. The bibliography lists about 100 titles up to 1855 or less than 10 per cent of the total of 1200 titles; see Fig. 1. The period of greatest activity in the study of color-blindness was between 1870 and 1890 and the interest has continued steadily up to the present time. From this extensive literature, the facts of color-blindness have been drawn. It is the purpose of this paper to present a summary of these facts, and it is hoped that they will be given essentially their proper emphasis and perspective in spite of the fact that only 80 of the 1200 publications have been studied in any detail. This summary has four parts, (a) classification of visual systems, (b) causes of color-blindness, (c) luminosity functions of red-green-blind and red-green-weak observers, and (d) chromaticity confusions of red-green-blind observers.

2. CLASSIFICATION OF VISUAL SYSTEMS

Seebeck's classification of vision into normal and two types of abnormal vision has been corroborated by scores of studies since 1837. In addition to these three classes many more have been established. Table I summarizes the characteristics of the chief classes of vision which are now fairly well established as well as several which are still subjects of controversy.

Normal vision, and indeed any type of visual system, may be conveniently summarized by giving a description of an equal-energy spectrum as it appears to an observer of that type. The equal-energy spectrum is one having constant radiance per unit wave-length. Every stimulus affecting the eye is either a portion of this spectrum or may be regarded as a combination of a number of such portions. We may therefore sketch approximately the properties of an observer by giving his description of the spectrum just as Dalton did for his own vision.

A. NORMAL VISION

To the normal observer the spectrum appears as a series of chromatic colors varying from dim red through orange, yellow, brilliant yellow-green, green, blue, to dim violet. The brightest part of the equal-energy spectrum under usual observing conditions is between wave-lengths 540 and 570 millimicrons (yellowish green), and from this point (average 555 mμ) toward both greater and smaller wave-lengths the brightness progressively diminishes. These facts are represented by the luminosity function of the average eye whose maximum is at 555 mμ. The colors seen by a normal observer can be duplicated with trivial exceptions by mixtures of three lights, a red light, a green light, and a blue light, each light being independently adjustable in amount; two lights are insufficient and more than three not necessary. On this account normal vision is classed as trichromatic. A corollary of trichromatism is that three kinds of discrimination are possible. It is convenient to classify the discriminations of a normal observer as light-dark, yellow-blue, and red-green; that is, a normal observer can tell light colors from dark ones, yellowish colors from blue ones, and greenish colors from red ones. For example, he can tell greenish grays from reddish grays, greenish yellows from reddish yellows. and greenish blues from reddish blues; these are all examples of red-green discriminations.

The types of abnormal vision may be classed under anomalous trichromatism, dichromatism, and monochromatism.

TABLE I. Classification and characteristics of the various visual systems.

Designation of type according to number of components	Discriminations possible by this type	Wave-length of the maximum of luminosity function, mu	Wave-length of neutral points in spectrum, mu	Non-theoretical designation (v. Kries)[1]	Theoretical designations Young-Helmholtz	Hering	G. E. Muller
Trichromatism	Light-dark Yellow-blue Red-green	555	None	Normal system	Normal system	Normal system	Normal system
	Light-dark Yellow-blue Red-green (weak)	540	None	Protanomaly[2]	Abnormal red function	——	Alteration[5] system
	Light-dark Yellow-blue Red-green (weak)	560	None	Deuteranomaly[2]	Abnormal green function	Red-green weakness	Alteration[5] system
	Light-dark Red-green Yellow-blue (weak)	560	None	Tritanomaly[2]	Abnormal violet function	Yellow-blue weakness	Alteration[5] system
Dichromatism	Light-dark Yellow-blue	540	493	Protanopia[7]	Red blindness	——	Outer red-green blindness
	Light-dark Yellow-blue	560	497	Deuteranopia[7]	Green blindness	Red-green blindness	Inner red-green blindness
	Light-dark Red-green	560	572	Tritanopia	Violet blindness	——	Youter yellow-blue blindness
	Light-dark Red-green	560	470 580	Tetartanopia[4]	——	Yellow-blue blindness	Inner yellow-blue blindness
Monochromatism	Light-dark	510	All	Congenital total color-blindness[8]	——	——	Cone blindness[6]
	Light-dark	560	All	Acquired total color-blindness[8]	——	Total color-blindness	Inner total color-blindness, Type I
	Light-dark	540	All	——	——	——	Inner total color-blindness, Type II

[1] See literature reference 28, p. 402.
[2] Konig (reference 25) proposed the designation, anomalous trichromatism, for the classes later designated separately by Nagel (reference 37) in an extension of the v. Kries terminology.
[3] This extension of the v. Kries terminology was proposed by Engelking (reference 4).
[4] This extension of the v. Kries terminology was proposed by Muller (reference 34, p. 68).
[5] The term, alteration system, was proposed originally by v. Kries (references 27, 28, p. 408); Muller also uses Nagel's terminology; see note 2.
[6] The term, cone blindness, is based upon the duplicity theory of v. Kries and Parinaud, now widely accepted (reference 33).
[7] Protanopic observers are sometimes called scoterythrous (reference 47), and deuteranopic, photerythrous.
[8] Total color-blindness is often called achromatopsia (reference 49) or achromatopia.

B. ANOMALOUS TRICHROMATISM

An observer possessing anomalous trichromatic vision requires a mixture of three lights to produce all the colors which he is capable of experiencing just as a normal trichromat does, but to produce a given color he requires proportions significantly different from those required by the normal observer. If he is only mildly anomalous, his description of the equal-energy spectrum will agree somewhat with the normal; but if he is extremely anomalous, it will scarcely differ from that of a dichromat. The distinctions made by such an observer are light-dark, yellow-blue, and red-green; but the ability to make one of the chromatic distinctions (usually red-green) is relatively weak. There are two fairly prevalent types of anomalous trichromat, called protanomaly and deuteranomaly, and a rare type, tritanomaly, recently discovered by Engelking.[4] Observers of these types are intermediate in ability to make chromatic distinctions between normal observers and dichromatic observers of the protanopic, deuteranopic and tritanopic types respectively, to be discussed presently. Thus, the anomalous observer can make with difficulty the distinctions which the corresponding dichromat cannot make at all. However, in other respects anomalous trichromatism is not intermediate between normal trichromatism and dichromatism. For example, the luminosity function of protanomalous observers of all degrees is deficient at the long-wave end like that of the protanope. This deficiency is indicated roughly in Table I by the average wave-length (540 mμ) of the brightest part of the equal-energy spectrum. The deuteranomalous and tritanomalous observers on the other hand have luminosity functions well within normal limits.

C. DICHROMATISM

An observer possessing a dichromatic visual system requires a mixture of but two lights to produce all the colors which he is capable of experiencing. He can make two kinds of visual discrimination, one achromatic (light-dark) and one chromatic (either yellow-blue or red-green, usually the former).

The spectrum to an observer having red-green blindness appears in two hues only; the short-wave end of the spectrum appears blue; the long-wave end, yellow (just as Dalton described it in 1798). These two bands are separated by a region at about 495 mμ which like average daylight has no hue at all, called the neutral point. From zero at the neutral point the saturations of the spectrum colors increase toward both the long-wave and the short-wave ends. There are two subtypes of red-

green blindness; one characterized by abnormally low luminosity of the long-wave portion of the spectrum, the other by a substantially normal luminosity function.

The first subtype is that possessed by Dalton and called by Helmholtz (p. 360)[14] *red-blindness* following Young's explanation. The nontheoretical designation of this type, protanopia, proposed by v. Kries,[27] is probably the most widely used.* This designation is an improvement over the theoretical designation, red-blindness, because such a term taken from Young's original hypothesis suggests that protanopes see nothing but green and violet, whereas cases of monocular protanopia have shown that they really see yellow and blue.[3] Adherents of the Müller theory of vision also use the designation "outer (or retinal) red-green blindness" because the Müller theory,[34] places in the retina the defect causing this abnormality of vision. The Hering theory does not account for it. An alternate descriptive term, scoterythrous,[47] is sometimes substituted for protanopic. In Table I the shortening of the long-wave end of the spectrum for protanopes is indicated by the average wave-length (540 mμ) of the maximum of the protanopic luminosity function. This wave-length is definitely, though only slightly, beyond the normal limits.

The second subtype of dichromatic vision is known as deuteranopia, formerly called green blindness by Helmholtz following Young's ex-

*By derivation the terms, protanopia and deuteranopia, are rather closely allied to the theoretical terms, red-blind and green-blind, which they were intended to replace. That v. Kries wished them to refer only to experimental facts is indicated by the following discussion (reference 28, p. 402) written by him in 1911.

"The connection thus established and experimentally verified between the two types of dichromats and between both of them and normal trichromats is identical with what Helmholtz had already supposed to be probably the case. In order to have a name for it that expresses simply the experimental results without involving any theoretical consequences, the writer speaks of the two colour systems of dichromats as being *reduction forms* of normal vision. At any rate the simplest and most natural explanation of these abnormalities is to regard them as being *deficiency effects*, in the sense that each of these types lacks one of the component factors of the visual organ as assumed in the Helmholtz theory. This was just the idea that was conveyed by the terms red-blind and green-blind that were formerly in use. And yet these expressions have been the source of much misunderstanding, for which the words themselves are perhaps partly responsible. As a matter of fact, green-blind persons are not really blind to green light, nor red-blind persons to red light; nor can it be assumed that the former lack the sensation of green and the latter the sensation of red. (Moreover, simply because the dichromat is supposed not to have some one of the three components of the organ of vision, we have no right at all to infer that ordinary heterogeneous daylight which has no colour for a normal eye looks blue-green to one kind of dichromat and purple to the other kind.) In order to have brief descriptive terms for the relation that has been found to exist here, without expressing any theoretical bias, the writer suggests the names *protanopes* and *deuteranopes* to describe the two kinds of dichromats, that is, persons who lack the first component or the second component, respectively, of the normal visual organ."

plantation. The Müller theorists call this abnormality of vision "inner, or neural, red-green blindness" because they place in the optic nerve the structural defect causing it. The luminosity functions of deuteranopes fall well within normal limits, but there is some indication that on the average they are higher than normal on the long-wave side; compare, in Table I, the maximum of the normal luminosity function (555 mμ) with that for deuteranopes (560 mμ). Deuteranopic observers are also sometimes known as photerythrous.[47]

Dichromatic vision may also take the form of yellow-blue blindness which is a rare form associated chiefly with diseases of the eye. Objects appear to such an observer a good deal as they do by candlelight to a normal observer. The spectrum to an observer having yellow-blue blindness appears in but two hues, red and green; his luminosity function is normal or nearly so, a possible slight defect on the short-wave end being hard to separate from the effects of yellow pigmentation of the eye media, which is very common. There are two subtypes of yellow-blue blindness.

The first subtype is called tritanopia. A tritanopic observer sees one neutral point in the spectrum (at about 570 mμ) which divides it into a red (long-wave) and a bluish green (short-wave) portion. The Young-Helmholtz theory gives it the name of violet blindness. The Müeller theory calls it "outer yellow-blue blindness" as well as tritanopia, in analogy to protanopia or outer red-green blindness. The Hering theory does not account for it.

The second subtype is called tetartanopia by Müller who also refers to it as "inner yellow-blue blindness" and makes it analogous to deuteranopia or inner red-green blindness. Tetartanopia is characterized by two neutral points in the spectrum, one at about 580 mμ, the other at about 470 mμ. To a tetartanope the spectrum appears red from the long-wave end down to the first neutral point, green between the neutral points and red again at the short-wave end. This type is so rare that many classifications fail to include it. Only 5 cases have been studied and reported. It is associated with impaired ability to distinguish red from green and therefore resembles to a considerable extent total color-blindness.[49]

D. MONOCHROMATISM

An observer possessing this type of abnormality requires but a single light to produce all the colors which he is capable of experiencing; he can match any two stimuli merely by adjusting them to equal brightness; he is capable of light-dark discrimination, but of no chromatic discrimination

whatsoever. His spectrum does not have merely one or two neutral points; it is all neutral. On this account monochromatism is rather aptly called achromatopsia or achromatopia.[49]

The most common form of monochromatism is often called cone blindness since it is universally ascribed to non-functioning of the retinal cones; the most common designation is congenital total color-blindness. Not only do monochromats of this type have at all times at least a trace of the central scotoma characteristic of normal twilight vision, but they also tend to have photophobia, or fear of light, which is characteristic of owls and of the normal dark-adapted observer, and which is ascribed to rod vision. Further common characteristics of such observers are low visual acuity and nystagmus or side-to-side eye-movements as if in an attempt to improve deficient visual acuity by using retinal areas now to the one side, now to the other side of a central blind area. The luminosity function of a cone-blind observer is the same as that of a normal dark-adapted observer; compared to the normal luminosity function it is greatly deficient on the long-wave side, and has a maximum at 510 instead of 555 mμ.

There are two less common forms of monochromatism both of which are thought to arise solely from disease of the eye and the optic nerve. Unlike cone blindness these forms are characterized by normal visual acuity as well as good foveal vision. The first type is characterized by a normal or deuteranopic luminosity function with maximum at about 555 mμ or 560 mμ; the second by a protanopic luminosity function whose maximum is at about 540 mμ. The second form is regarded as the result of an observer being born with protanopic vision and then acquiring tritanopia as a result of disease. Both are known as acquired total color-blindness.

3. CAUSES OF COLOR-BLINDNESS*

A. CONGENITAL COLOR-BLINDNESS

All forms of visual system except the two atypical forms of monochromatism just discussed may be inherited; the abnormal forms may therefore be considered as congenital defects. Protanopia, protanomaly, deuteranopia, and deuteranomaly are regarded as sex-linked characteristics.[43, 55, 59] According to this view, a mother with normal color sense may transmit any of these defects to her sons, but her daughters by a normal father are either normal or become themselves transmitters of the defect. Color-blind daughters result either from the union of a color-

*Prepared in collaboration with Dr. LeGrand H. Hardy.

blind man with a woman who is a transmitter of the same type of defect, or from parents both of whom have the same defect. By this view congenital color-blindness should be much more prevalent among males than among females. Table II, based chiefly upon the study of 5000 school children by v. Planta[43] and 18,000 school children by Waaler,[55] shows how closely the statistical facts agree with this view. Eight per cent of the boys were found to possess a color defect, while less than one-half of one per cent of the girls were color-blind. It is obvious, however, that by this view at least 8 per cent of women must be transmitters of color-blindness.[55]

Total color-blindness is only slightly more prevalent among males than females. Estimates of the frequency of occurrence of total color-blindness have also been included in Table II, and are based upon Köllner's[24] summary of studies by Göthlin[8] and Peter.[40] Total color-blindness is regarded as a simple recessive characteristic; total color-blinds are frequently found to have parents having close blood relationships.

The estimates of one ten-thousandths of one per cent for the occurrence of tritanomaly and tetartanopia correspond to three cases of tritanomaly,[4, 5, 11] and five cases of tetartanopia reported in the literature.[1, 15, 16, 34, 45, 46, 52, 53] All three cases of tritanomaly were closely related males; so there is some evidence that this defect is also sex-linked. Congenital tritanopia is but rarely studied and reported. Perhaps such cases are less seldom detected because the practically important red yellow, and green colors can be distinguished from each other by them, though they cannot distinguish yellow from light gray. At any rate, a reliable estimate of the frequency of occurrence of congenital tritanopia cannot be made. The figure given in Table I (one out of a million males) corresponds to five cases reported in the literature[17, 23, 29, 41, 56] some of which might have been acquired tritanopia rather than congenital.

B. ACQUIRED COLOR-BLINDNESS

Acquired color-blindness (central or peripheral defect or scotoma for colors) occurs in all diseases affecting the central retina or its tracts in the optic nerve, the optic tract, or the optic cortex. The most common disease of the central nervous system which causes central field defects (both for form and color) is multiple sclerosis. Several generalized non-infectious diseases cause optic neuritis with attendant loss of color and form discrimination. The most common are blood dyscrasias (pernicious anemia, secondary anemia, or lukemia) and deficiency diseases (B1 deficiency, so called "diabetic amblyopia," and optic neuritis of pregnancy).

The most common occurrences of central color field defect are in connection with toxic amblyopia, and those toxins which most commonly depress the central (as opposed to the peripheral) field are:

TABLE II. Frequency of occurrence of inherited visual systems.

Designation by number of components	Non-theoretical designation (v. Kries)	Percentage of the population that have these visual systems Male		Female	
Anomalous trichromatism	Protanomaly	1.0		0.02	
	Deuteranomaly	4.9		0.38	
	Tritanomaly	0.0001		0.0000	
			5.9		0.40
Dichromatism	Protanopia	1.0		0.02	
	Deuteranopia	1.1		0.01	
	Tritanopia	0.0001		0.0000	
	Tetartanopia	0.0001		0.0000	
			2.1		0.03
Monochromatism	Total color-blindness	0.003		0.002	
Abnormal systems			8.0		0.43
Normal system			92.0		99.57

Carbon disulfide—used in preparation of rayon, rubber, explosives, hides, insecticides, and wall paper.

Lead poisoning found in painters, plumbers, riveters, storage battery workers and compositors.

Spinal anesthesia.

Sulfanilamide—may cause optic neuritis or hemorrhages into optic nerve.

Snuff, iodoform, and stramonium—rare cases.

Thallium—used in industry as a rat poison and a depilatory.

Tobacco-alcohol—the most common of all the agents producing amblyopia.

Toxic agents and disease affecting the conducting (transmissive) elements of the optical apparatus (nerve fiber layer of retina, optic nerve, and tract) are classically supposed to cause red-green weakness distinguished from deuteranomaly only by having poorer light-dark and yellow-blue discriminations. This defect becomes progressively worse until red-green blindness is reached which is distinguished from deuteranopia chiefly by its poorer light-dark discrimination. Finally total color-blindness results.

On the other hand, injuries (such as produced by syphilitic infections[26]) which primarily affect the receptive (rod-cone) mechanism show first a depression of the ability to make blue-yellow discrimina-

tions. Acquired tritanopia, unlike acquired red-green blindness, may become stabilized and be distinguished from congenital tritanopia chiefly by the memory possessed by the subject of his former yellow and blue sensations. Acquired tritanopia leads to total color-blindness only when progressive red-green blindness ensues; the latter, however, may of itself lead to total color-blindness[22] as noted above.

There is no therapy for acquired color-blindness since this is merely a symptom. The therapy is directed towards the underlying cause. The return of normal vision is usually by stages the reverse of those which characterized the disease.

In addition to acquired color-blindness which prevents the subject from seeing colors which are normally present, some mention should be made of chromatopsia which refers to the vision of colors which are normally absent. Erythropsia, or red vision, is the most frequent. It occurs normally after the eyes have been exposed to a very bright light, such as sunlight reflected from snow. Since in erythropsia the bright portions of the visual field are tinged with bluish red and the dark portions with yellowish green, the name is only half accurate. Erythropsia, however, is often a source of anxiety to a patient on the sudden access of light to the retina after a cataract extraction, iridectomy, or even when the pupils have been dilated by atropine. It is probably due to the prolonged and predominant red phase of the after-image.[54, 60] Cyanopsia, blue vision, may form a fleeting symptom after cataract extraction, probably owing to the previous influence of adaptation to the yellow color of the lens, since before extraction the short-wave light had all been absorbed. It also occasionally is a rare symptom in poisoning (as by digitalis) or in diseases of the retina and choroid, as also is (very rarely) ianthopsia, violet vision, and chloropsia, green vision. Xanthopsia, yellow vision, is said to be a somewhat more common symptom of jaundice and also occurs in picric-acid poisoning.

C. COLOR-BLINDNESS OF THE TRICHROMATIC OBSERVER

Lest it be forgotten that chromatic vision is normal under very special conditions, the following circumstances are listed under which normal eyes are color-blind:

I. *Indirect vision,*—vision in the retinal regions somewhat removed from the fovea differs from deuteranomaly only by reduced light-dark blue-yellow, and form discrimination; vision in a more peripheral zone differs from deuteranopia only in these same ways; and vision in the

periphery differs from acquired total color-blindness only by reduced ability to make form and light-dark discriminations.

II. *Insufficient size,*—a luminous area of a given brightness perceived by the para-foveal region may, by reducing its area sufficiently, be made to fail to elicit any chromatic color although still easily visible. For such areas the normally trichromatic para-foveal region becomes characterized by a monochromatic visual system, the type being indistinguishable from acquired total color-blindness.

III. *Insufficient brightness,*—the normal dark-adapted eye is in every respect functionally identical with that of the congenitally total color-blind.

IV. *Insufficient time,*—a luminous area may be perceived as brightness when exposed for so short a time that no chromatic color is experienced. Under these conditions, as in flicker photometry, the normal eye makes light-dark discriminations only, the type of vision being closely like acquired total color-blindness.[62]

V. *Chromatic fatigue,*—a form of artificial color-blindness can be produced temporarily (for a few minutes) by flooding the eye with a high luminous flux of chromatic light. In addition to rendering the eye insensitive to red, green, blue or violet light, whichever is the color of the fatiguing light, there is a shorter positive after-image of this light. This could be described as temporary chromatopsia.

The ability to overcome these handicaps to chromatic vision renders one normal observer much more valuable than another. For many tasks, particularly war-time tasks, that observer is more valuable who is not troubled by chromatic fatigue, and who can distinguish correctly the colors of small, dim, briefly visible objects even though he "catches them only in the corner of his eye." It has been found that on the average anomalous trichromats are much more susceptible to impairment of their chromatic vision by these circumstances than are normal observers. For example, they are said to experience chromatic contrast effects much greater than normal which interfere with their correct perception of colors. Because of this average susceptibility to handicaps, there has been a disposition to disqualify all anomalous trichromats for tasks to which dichromats are unfitted. Thus, it is stated by v. Kries (p. 409),[28] "We are indebted especially to Nagel's investigations[36, 38] for light on this subject. Donders had long ago expressed the view that such persons had a 'dim sense of colour.' This indeed has now been thoroughly established; that is, the anomaly of the colour system (in the sense of having to make a

different setting for the Rayleigh equation)[44] can be considered as an important and sure sign of 'colour infirmity'."

And again (p. 421),[28] "From the practical standpoint, the thing of most importance, . . . , is that not only dichromats but persons with anomalous vision also are below par in a number of respects, and they are particularly unsuitable for railway or marine service. This, therefore, to a certain extent is the chief reason for improving the methods of investigation. The examination of these people is the right way of going at the problem of finding out all persons with abnormal colour vision and eliminating them."

There is a question, however, whether to paint all anomalous trichromats with the same brush may not unjustly disqualify certain of them for tasks which they are perfectly capable of performing. Thus, Köllner remarks (p. 515),[24] "From the foregoing it follows that red-green imbalance (rotgrünungleichheit), by which anomalous trichromats are characterized, plainly has nothing to do with the red-green sensation. 'Anomalous trichromasy' and 'red-green weakness' do not mean the same thing; by the former we have supersensitivity at least for one color, and on the other hand in spite of the absence of red-green imbalance there can occur a deficiency of the red-green sensation. Anomalous trichromasy is characterized by a 'constancy' of the red-green imbalance (see above) and is sharply separated from the normal proportions; the degree of red-green sensation on the other hand can vary widely and all steps from color-blindness up to the normal average can exist, indeed it can exceed that average. As to the color vision of anomalous observers, one can say in general with respect to their decreased red-green sensation relative to the normal that under favorable observing conditions they see practically as well as the normal, but under unfavorable circumstances they can approach the condition of the red-green blind very closely or even equal it."

These views are largely borne out by the findings of McKeon and Wright[32] who say, "The family of hue discrimination curves shows clearly how successive degrees of the defect are revealed in an increasing inability to distinguish different colours. The curves form a continuous series between the curve for the normal trichromat and that for the protanope as reported by Pitt.[42] . . . The luminosity and mixture curves . . . show comparatively little variation among themselves, and there is some justification for deriving a mean curve for the 11 observers."

Köllner's statement is also borne out by Nelson (p. 687)[39] who states, "If the differences between the normal and anomalous hue-dis-

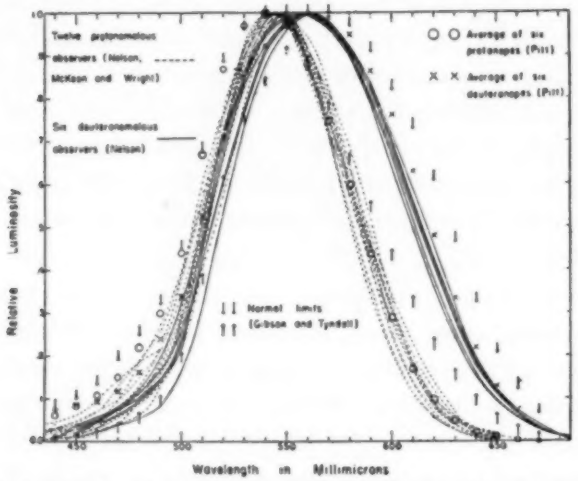
Twelve protanomalous observers (Nelson, McKeon and Wright)
Six deuteranomalous observers (Nelson)
O O Average of six protanopes (Pitt)
X X Average of six deuteranopes (Pitt)
Normal limits (Gibson and Tyndall)
Relative Luminosity
Wavelength in Millimicrons

Fig. 2. Relative luminosity functions of anomalous trichromats (6 deuteranomalous, 12 protanomalous) compared to averages for dichromats and to limits for normal trichromats. Deuteranopic and deuteranomalous luminosity functions fall generally within normal limits; but protanopic and protanomalous luminosity functions fall outside of normal limits.

crimination curves are taken as a measure of the degree of deficiency of the observer, then it can be seen that the other characteristics cannot always be treated as an obvious guide to the extent of the defect. . . . This apparent discrepancy between the various characteristics is particularly noticeable as regards the position on the Nagel distribution curve (Rayleigh equation). For example, in the case of observers *A* and *D* . . . , *A* is farther from the normal on the Nagel curve, but his hue-discrimination is the more nearly normal."

The facts of protanomaly and deuteranomaly are therefore such as to raise the question whether this classification has very much practical value. After a subject has been found to be an anomalous trichromat, the question still arises as to what he is good for.

4. LUMINOSITY FUNCTIONS OF RED-GREEN-BLIND AND RED-GREEN-WEAK OBSERVERS

Figure 2 shows by dotted lines the luminosity functions of eleven protanomalous observers studied by McKeon and Wright[32] and one studied by Nelson.[39] It also shows by solid lines the luminosity functions of six deuteranomalous observers studied by Nelson.[39] Although at the short-wave end of the spectrum these groups of functions overlap and are

not significantly different, the two groups divide quite sharply at the long-wave end. In this respect they are like the groups of functions representing the two corresponding types of dichromatic observer, the deuteranope, and the protanope. The circles represent the average of six protanopic luminosity functions evaluated by Pitt,[42] and the crosses represent his average of six deuteranopic luminosity functions. The arrows indicate the maximum and minimum values of relative luminosity found by Gibson and Tyndall[6] among their 37 completely studied normal observers. Although because of differences in experimental conditions no highly precise intercomparison is possible between the data shown for anomalous and dichromatic observers and these normal limits, nevertheless Fig. 2 indicates that the deuteranopic and deuteranomalous observers alike possess luminosity functions generally well within normal limits; but both protanomalous observers and protanopic observers possess luminosity functions that are abnormally low at the long-wave end.

Figure 2 tends to indicate also that protanomalous observers possess abnormally narrow luminosity functions even compared to protanopes; but because of the small number of cases this indication may fail to be significant. On this account in Table I the maximum of the protanomalous luminosity function, like that of the protanope, is given as 540 $m\mu$, although Fig. 2 indicates that 545 $m\mu$ might be a slightly better value. The experimental conditions (field size, field luminance, surrounding-field luminance) and technics (adaptation, control of fixation, length of observing time) govern the participation of the rod mechanism in determining these functions. In any one study the luminosity curves may be thrown more or less to the short-wave side because of partial participation of the rods, either intended or inadvertent. The intertwining of the curves at the short-wave end is probably to be ascribed chiefly to individual variation of the amount of yellow or brown pigmentation of the eye media, such as degree of macular pigmentation.

Since from Fig. 2 both deuteranopic and deuteranomalous luminosity functions fall generally within normal limits, it is just as valid to predict the brightness judgments of these abnormal observers from the standard luminosity function as it is those of a normal observer. Thus, for normal, deuteranopic and deuteranomalous observers alike, the relative luminosities of two colors specified by (X_1, Y_1, Z_1) and $X_2, Y_2, Z_2)$ in the standard ICI colorimetric coordinate system,[10, 20] may be judged by a comparison of Y_1 with Y_2.

For protanopic and protanomalous observers, however, colors

which are red to the normal observer are significantly darker relative to other colors. Figure 3 shows that it is possible to deduct from normal luminosity a correction for the redness of the color and so arrive at a protanopic and protanomalous evaluation of luminosity. Instead of comparing the Y values, use should accordingly be made of the values of the function: $0.086Z+1.160Y—0.393X$. Figure 3 shows this function for the equal-energy spectrum compared to the upper and lower limits of 18 protanopic and protanomalous luminosity functions (6 protanopic functions determined by Pitt, 12 protanomalous functions determined by Nelson, and by McKeon and Wright). Since the tristimulus values, X, Y, Z, are known for many colors, the function $0.086Z+1.160Y—$

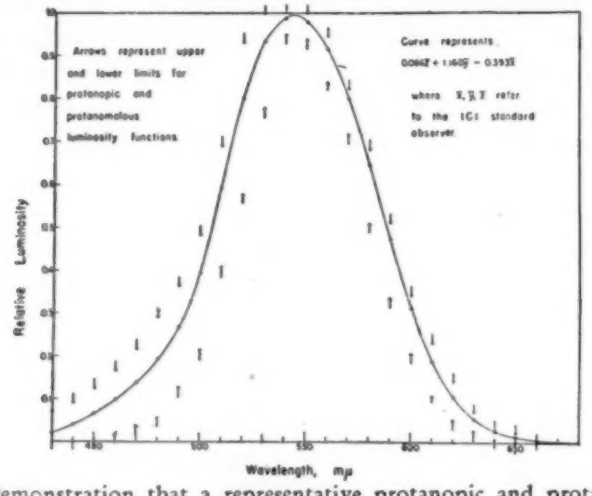
Arrows represent upper and lower limits for protanopic and protanomalous luminosity functions
Curve represents
where X, Y, Z refer to the 1931 standard observer
Relative Luminosity
Wavelength, mμ

Fig. 3. Demonstration that a representative protanopic and protanomalous luminosity can be computed from the normal specification of any color. Instead of normal luminosity, Y, use $0.086Z+1.160Y—0.393X$.

$0.393X$ is quite useful: for example, the tristimulus values of the Munsell colors are known,[7,21] hence, by this function there can be determined with good validity which of any two surface colors of given Munsell notation will appear lighter either to a protanope or to a protanomalous observer. Such information is of assistance in the design of color-blindness tests.

Thus, it is seen that the facts of color-blindness are such that the brightness judgments of abnormal observers of the most common types may be conveniently predicted from the same color specification used for normal observer.

5. CHROMATICITY CONFUSIONS OF RED-GREEN-BLIND OBSERVERS

The outstanding characteristic of a dichromatic observer which per-

mits him to be distinguished from an anomalous trichromat is that although he makes important chromaticity confusions, he does not object to color matches set up by a normal observer between two fields of different spectral composition. On this account dichromatic visual systems are called reduction systems, and it is possible to derive from the normal specification of a color an adequate specification of the color for a dichromatic observer. With anomalous trichromatic observers, it is, of course, quite otherwise.

In 1885 Maxwell[30] pointed out from the Young-Helmholtz theory, how to define the chromaticity confusions of the color-blind in terms of the color triangle, now known as a chromaticity diagram. By this theory a dichromatic observer differs from the normal trichromatic observer by lacking one of the three primary color responses. The chromaticity for a dichromatic observer is therefore wholly determined by the ratio of the two remaining responses. For this ratio constant, there is defined on the normal chromaticity diagram, a straight line passing through the point representing the missing primary. A family of straight lines on the Maxwell triangle all passing through this point, therefore, represent by this theory all of the chromaticity confusions of the dichromatic observer.

Although the Young-Helmholtz theory is no longer regarded as a completely adequate basis for explaining color-blindness, this particular

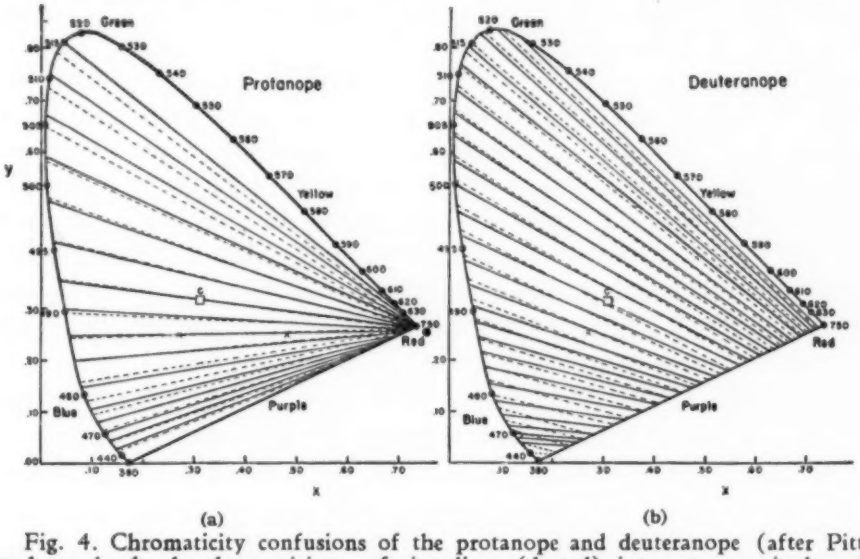

Fig. 4. Chromaticity confusions of the protanope and deuteranope (after Pitt). Note how closely the chromaticity-confusion lines (dotted) intersect at a single point for each of the two common types of red-green blindness. The solid lines included for comparison are co-punctal (protanope at x=0.747, y=0.253; deuteranope at x=1.000, y=0.000).

prediction from the theory was verified in a very satisfactory way in 1935 by Pitt.[42] Pitt found that the lines representing the chromaticity confusions converge closely on a single point, both for the protanopic observer and for the deuteranope. Figure 4a shows as dotted lines on the (x,y)-chromaticity diagram of the ICI colorimetric coordinate system[10,20] the results of Pitt's determination for protanopic observers; and Fig. 4b shows similarly the results for deuteranopic observers. The families of solid lines drawn in for comparison pass through a common point in each case (protanope: x=0.747, y=0.253; deuteranope: x= 1.000, y=0.000). The spacing of the lines has been adjusted by Pitt from his determination of chromaticity sensibility to wave-length change for dichromats so that the chromaticity represented by one line is just distinguishable from that represented by its neighbor. It may be seen that the failure of the dotted lines to converge to a single point in the case of the protanope is not significant, and for the deuteranope is scarcely significant.

As remarked by Pitt (p. 44)[42] these results together with the luminosity data just presented "are of the most fundamental kind for dichromats, and on such measurements are based, either knowingly or unknowingly, all colour-blind tests." It will be worthwhile, therefore, to inquire further into the interpretation of Fig. 4.

In Fig. 4a there is a confusion line passing nearly through the point representing ICI standard illuminant *C* (average daylight). This line passes through the spectrum locus at about 493 mμ. From this line it may be concluded that Pitt's average protanope will not be able to distinguish the chromaticity of illuminant *C* from that of the spectrum at about 493 mμ; that is, his neutral point is at 493 mμ as is indicated in Table I. However, the position of the neutral point is subject to rather large individual variations as is shown by Hecht and Shlaer.[12] These variations are to be expected because of the dependence of the chromaticity of illuminant *C* on degree of macular pigmentation, which does not affect the chromaticity of spectrally homogeneous light at all.

Similarly, from Fig. 4b it is seen that the average deuteranopic neutral point for Pitt's six observers occurs at about 497 mμ.

From this neutral point the red-green-blind observer sees yellow of increasing saturation up to a wave-length of about 530 mμ after which there is no further chromaticity change. In the direction of decreasing wave-length the dichromatic observer sees blue of saturation increasing to the end of the spectrum. Note how apt was Dalton's description of

the spectrum: "My yellow comprehends the red, orange, yellow, and green of others; and my blue and purple coincide with theirs." We must take Dalton's purple to mean saturated blue.

This description of the spectrum fits both protanope and deuteranope, and we may ask how Seebeck[48] could deduce that Dalton was a protanope. This deduction follows from Dalton's further statement, "Woolen yarn, dyed crimson, or dark blue is the same to me." Assuming that the names, crimson and dark blue, have retained their meaning over the intervening 100 years, we may use Fig. 4 to check this deduction. Harvard Crimson[50] is found by way of the Munsell color system to have x=0.48, y=0.25; dark blue (Navy 1)[50] is similarly found to have x=0.27, y=0.25. These points are indicated on Figs. 4a and 4b by crosses. From Fig. 4a it may be noted that an average protanope is expected to confuse these chromaticities, since the points representing them lie on the same line; but from Fig. 4b it should be anticipated that to the average deuteranope crimson would appear as a brownish gray quite distinct from the appearance of dark blue which would be seen correctly.

Thus, it is seen that the facts of red-green blindness are such that the chromaticities experienced by such observers can be predicted from the same standard color specifications used by the normal observer. For example, the points representing on the (x, y) -diagram the standards of the *Munsell Book of Color*[35] are known.[7, 21] Therefore, from the Munsell notation of a color may be obtained a reliable indication of its chromatic appearance to a red-green-blind observer.

6. SUMMARY

Color-blindness is of various types, and there is a greater or lesser adherence of groups of observers to these types. The most common are the two types of red-green blindness, protanopia and deuteranopia, and the corresponding types of anomalous vision, protanomaly and deuteranomaly. Although red-green-blind observers should obviously be excluded from occupations requiring the ability to make red-green distinctions, there is doubt what to do with an observer proved to be anomalous because in spite of the fact that many anomalous observers have virtually no ability to distinguish red from green, others do so nearly or quite as well as normal observers.

Color-blindness is usually congenital, but it may also be acquired as a result of injury or disease. Congenital red-green blindness and anomalous vision are much more prevalent among males than among females, and are regarded as sex-linked characteristics. Total color-blindness, how-

ever, is thought to be a simple recessive characteristic.

Red-green blindness is designated as a reduction form of normal vision because two lights of whatever spectral compositions are required to produce a match for the normal observer will also be indistinguishable by a red-green-blind observer. Red-green weakness, or anomalous vision, on the other hand, is called an alteration form of vision, because such matches by the normal are frequently quite unacceptable to the anomalous observer. In spite of this it is possible to predict the brightness judgments of the anomalous observer with good validity from the normal specifications of the colors being dealt with, the chromaticity alone being unpredictable. Methods of predicting precisely the appearance of colors to red-green-blind observers are described with a view to their possible usefulness in the design and development of color-blindness tests.

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AMERICAN JOURNAL OF OPTOMETRY
and ARCHIVES *of*
AMERICAN ACADEMY OF OPTOMETRY
Established 1924

Vol. 21 JANUARY, 1944 No. 1

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Annual Subscription, $4.00 in Advance; Canada, $4.50; Foreign, $5.00;
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Published Monthly by the
AMERICAN JOURNAL OF OPTOMETRY PUBLISHING ASSOCIATION

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OPTOMETRISTS HAVE A STAKE IN THE ASSAULT ON PRICE CONTROL

An optometrist inquires why price control is getting such a pounding at Washington. The fundamental answer is, that it has been working. And for this all professional people should be thankful.

The cost of living index has risen by less than 5 per cent in the past year. The wholesale price index has gone up only 3 per cent. As the NEW YORK JOURNAL OF COMMERCE observes, "When we stop to consider the magnitude of the task, particularly in view of the unwilling-

ness of the Administration to adopt timely and realistic wage and tax policies to implement the OPA's efforts, the accomplishment is indeed considerable."

The outcry going up from special interest groups to take off this lid is nothing in comparison to the one that would arise from the public as a whole if they were to succeed and a rapid rise in the cost of living were to occur.

Likewise the present controls and regulations, onerous as some of them may be, will be mild and gentle in comparison with those that would follow from an experience with real price inflation.

Relatively to what happened in the last war, prices have gone up only moderately in the past four years, a matter of about 25 per cent. In this country most of this increase took place between January and September, 1942. Since serious control began, prices have been kept on a surprisingly even keel. There are some exceptions, but taking all the costs of living into consideration, the total achievement has been good. As a result the number of persons who have been hurt by the rise of prices is comparatively small. Most families have maintained or improved their financial status and their standard of living, many very substantially.

Consequently, the only people who are agitated about price control are those who want to upset it. The great majority are satisfied, passive and innocently oblivious of the very real danger that real and crushing inflation is just around the corner.

If Congress allows the slaughter of price control, and as these notes are being compiled during the middle of December, 1943, the subject is before them—then we Americans are in for a very unpleasant time on the home front. College professors, professional people and white collar workers in general will take a bad beating and in the end the public reaction will be such as to cause those now discontented to wonder why they did not leave well enough alone.

CAREL C. KOCH.

COMMISSIONS FOR U. S. ARMY OPTOMETRISTS

More than two years have passed since our country's entry into the war and the most that has been accomplished for many of our optometrists in the army are sergeant ratings. And they are by no means assured

of this. Many optometrists are doing refractions, day-in-and-day-out in our army hospitals, and are serving as privates. One of these has this to say, "In just a year my brother will graduate from high school. He has already spoken of entering an Optometric School. So far I am set against it and refuse to allow him to enter the profession, unless he can keep his head high with full recognition of his title, Doctor. I am passing through this stage of the mop, guard duty, detail and retinoscope and I want no part of this for my brother. I also know he has friends who are interested in Optometry.

"When the men in my own detachment place no confidence in me, by insisting that an Officer examine them, what will my patients think when I return to civilian life. Questions will be asked by them as to the position I held. Will I have to make excuses then as I must now? No confidence can be placed in an enlisted man. This only brings shame upon us and it does, because we are at times placed in such a position that shame can be the only result.

"I am looking forward to the leaders of Optometry to help us and I would be glad to assist in any possible way that you might suggest."

Sooner or later this war will end. Army optometrists will return and demand of our leadership an accounting of their stewardship during the war period. Unless action is started at once in securing commissions for army optometrists, the optometric association charged with initiating this type of activity is apt to be in for some difficult times and the leaders of this association will reap certain criticism.

And how different this all might be. At the start of the war Australian optometrists were faced with the same problem. With aggressive leadership and a determination to really contribute to the utmost in the war effort of the profession, they achieved the goal so urgently sought for here. Lieutenant R. K. Weller, optometrist from Adelaide, South Australia has this to say, "Optometrists in Australia are, to some degree isolated although the present world conflict has lessened our insularity and we have become more attached to the U. S. A. than in pre-war days. Despite this isolation we hold a certain amount of pride in our profession and the standards which we have attained.

"From time to time I have read of the difficulties which our colleagues in U. S. A. have encountered in attempting to gain recognition from the Army; I believe the position is even more acute in Great Britain. You may be interested to hear of the activities of the Australian Optometrist in Army life.

"The Optometrist in the Australian Army is granted the rank of First Lieutenant, (there is a possibility of promotion to Captain) and is attached to the Australian Army Medical Corps. He is usually drafted to a Base Hospital where he works cooperating with the Ophthalmologist of that Unit. Since inception there has been most friendly cooperation between the Ophthalmologist and the Optometrist and from my experience (I am serving as an Optometrist to the Army) the services rendered by the Optometrist have been appreciated.

"An Optical Unit consists of Lieut. Optometrist; Staff Sergeant, mechanic; and a Corporal."

There is still time to also achieve the end which all American optometrists seek. All optometrists doing refractive work in the U. S. Army should do so only as commissioned officers. Nothing else will satisfy optometrists both in and out of the army. Individually the members of our profession are articulate on this subject. There should be no further delay on the part of our association leaders.

CAREL C. KOCH.

REPORT OF THE AMERICAN OPTOMETRIC ASSOCIATION COMMITTEE ON ECONOMICS

This report[1] deals with the transition now taking place in optometry—the change-over of practice from emphasis on materials to emphasis on visual care. Many optometrists have completed this change. Others have never practiced in any other way and so have no material changes to make. However, there are still a number of optometrists who yet have an economic housecleaning before them, and the authors in this report suggest a number of small but important changes for these men to ponder upon and to then put into practice.

The report suggests, for those individual practitioners who still have these changes to make, no immediate startling upsets in their present routines. In fact the greatest changes must first come in their thinking —thinking towards their work—their patients welfare and their profession. And what is important too—thinking towards their future as professional men whose lives must be remoulded to fit into the public health programs of the post-war era.

[1]Edmund F. Richardson, Robert Foster Ash and Allen C. Holland. Report of the Committee on Economics. New Highways for Old By-Ways. American Optometric Association. 24 pages. October, 1943.

It is safe to assume that in any program of public health the practitioners will be selected to participate only if it can be shown that the practitioner himself is primarily interested in the service he can render the patient, and not primarily in the materials he may dispense in rendering this service. Of course the materials are important—in optometry we could not survive without them and we want them as fine and as good as it is possible for our manufacturers to make them—but in optometry we must all realize that the materials are secondary to the purpose for which they are prescribed.

This, then, is the first thesis, the optometrists attitude towards his work. Is he interested in visual efficiency or the dispensing of materials? Is he interested in serving the very best interests of his patients or in placing lenses and frames in their possession? Does he view his practice of optometry as a sacred trust granted him by the State to serve the public well or does he view his place in the optometric world as a stepping-stone towards the sale of quantities of ophthalmic materials?

In this report the authors discuss these points and review for the reader the essential steps to be taken by any practitioner to bring his individual practice within the bounds and scope of proper economic and professional service to the public. This short report should be *must* reading for many of our practitioners in optometry.

CAREL C. KOCH.

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

by J. Fred Andreae, Secretary

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

ACADEMY ANNUAL REPORT

The year 1943 has been a quiet one for the Academy, principally because there was no annual meeting. Nevertheless, the Executive Council met and members of the various committees carried on as usual.

A business meeting was held in Cleveland, Ohio, on August 14th and the following Fellows were in attendance: President Arthur P. Wheelock; Secretary J. Fred Andreae; William Greenspon, Bluefield, West Virginia; Don R. Paine, Topeka, Kansas; Ernest A. Hutchinson, Los Angeles, California; Dan R. Hummel, Cleveland, Ohio; Robert

M. Hall, Cleveland, Ohio; Carl Radde, Cleveland, Ohio; Irvin Borish, Chicago, Illinois; O. H. Johnson, Jonesboro, Arkansas; William S. Brent, Barberton, Ohio; Elias J. Margaretten, New York City; Glenn Fry, Columbus, Ohio.

An accumulation of business from the date of the last business meeting in Chicago in May, 1942 requiring the attention of the Executive Council was disposed of. The agenda included reports on Examination for Candidates, Secretary-Treasurer Report, publication of the Radde book "The Spatial Sense and Movements of the Eye," local chapters of the Academy, establishment of Junior Academies in the optometry schools, student procurement, professional practice and the annual meeting program.

The report of the committee on local chapters was most interesting. These chapters offer membership to optometrists meeting Academy requirements and the opportunity to prepare for subsequent Fellowship in the American Academy. Since the Cleveland meeting a chapter has been organized in Los Angeles, California, with Ernest A. Hutchinson as chairman and William R. Ketchum as secretary. It has been holding monthly meetings and at each meeting there are guest speakers from allied professions. Prospective member optometrists are invited to attend. The chapter members are enthusiastic over the interest being shown and the practical value of these monthly gatherings. A period is set aside for the discussion of pending refractive and treatment cases. A verbatim transcript of addresses and discussion of case problems is made and many of them will be published in these Archives from time to time.

Professional optometry would profit greatly from the establishment of local chapters in every community. Such establishment would permit the meeting together of optometrists who act and think alike and eventually bring about a much-needed uniformity in methods of practice. Many knotty problems affecting procedure in difficult cases could be discussed and solutions offered. Optometrists interested in the establishment of a local chapter are invited to address the secretary of the Academy for complete detail governing procedure.

Fellow Irvin Borish affiliated with the Northern Illinois College of Optometry offered the suggestion for the establishment of Junior Academies in the optometry schools. Membership in these academies would be predicated upon high scholastic standing and eventually lead to Fellowship in the parent body. The Academy would assume a parental interest in the members of these junior academies after graduation

and lend a helping hand in the building of a professional practice. The value of these junior Fellows to the continued successful advancement of Academy aims and ideals is immeasurable and means much to the entire optometric profession.

The report on the sale and distribution of the Radde book was gratifying and most satisfactory. Every progressive optometrist should have a copy of this book in his library. It contains a wealth of material applicable to present-day practice and procedure.

Fellow Dan Hummel, chairman of the Annual Meeting Program, reported an addition to the educational program of a symposium on actual office practice and stated he has the assurance of a number of original papers from Fellows admitted since the last meeting in Chicago, in December, 1941.

A new section has been added to the present By-Laws covering admission to Fellowship. It permits acceptance of eligible optometrists having practiced for a period of twenty years or longer, without the necessity of examination. Optometrists qualifying under this section can apply to the secretary of the Academy for application blank and complete details.

The Committee on Research reported progress on the selection of a subject for research.

Two members of the Executive Council are in the service of the armed forces of the Government. They are commissioned officers Edwin Dewey of Battle Creek, Michigan, and Harold Fisher of New York City. Both are stationed at Camp Eustice, Virginia and are doing specialized work. In addition to Fellows Dewey and Fisher, we have been advised the following Fellows are also in the service: R. C. Baxter, Jr., Warren, Ohio; R. F. Coops, Los Angeles, Calif.; J. H. Gregory, Benton Harbor, Mich., and H. D. Tansley, Kenora, Ontario.

Fellows of the Academy in the service are exempt from dues for the duration and for six months thereafter.

We regret to announce the death of the following Fellows: J. H. Drakeford, New York, N. Y.; Frank K. Moss, Cleveland, Ohio; J. F. Morrow, Jr., Pennsylvania; John Corbett, Boston, Mass.

Fellowships have been conferred upon the following since the last annual report: Joseph Greger, Cleveland, Ohio; J. L. Frank, New Prague, Minn.; R. H. Ehrenberg, Granite Falls, Minn.; Irwin Borish, Chicago, Ill.; G. L. Du Plessis, Minneapolis, Minn.; Eugene Freeman,

Chicago, Ill.; E. C. Deacon, Los Angeles, Calif.; J. R. Dean, Los Angeles, Calif.; H. E. Goodman, Los Angeles, Calif.; F. S. Leverich, Aurora, Ill.; H. B. Kollofski, St. Paul, Minn.; E. H. Morrissey, Los Angeles, Calif.; T. E. Miller, Elgin, Ill.; Neville Schuler, British Guiana, South America; A. R. Rochte, Port Ridge, Ill.; L. F. Madigan, Boston, Mass.; C. P. Nelson, Minneapolis, Minn.; W. H. Rukenbrod, Canton, Ohio; J. J. Sampson, Colorado Springs, Colo.; H. C. Sherratt, Minneapolis, Minn.; H. D. Tansley, Kenora, Ontario; Wendell Thriller, Hanover, N. H., and E. W. Larsen, Hibbing, Minn.

SPECIAL REPORTS

OPTOMETRIC STATUS IN A WAR PERIOD AND A LOOK TO THE FUTURE*

Philip N. Richmond, Opt.D.†

It seems only yesterday that as unmolded striplings we spoke our first hellos to each other, our college and our profession. All too brief, all too fleeting has been the interlude from that day to this. Tonight the curfew rings on undergraduate days, and we bid fond goodbyes cherishing the hope that they are but temporary, that we shall be reunited in future alumni and professional activities. These treasured college years with their bountiful myriads of pleasant memories have wrought their transformation upon us. We still are individuals; that is our heritage in a democracy—yes, we still have our idiosyncracies and controversies, our New England aloofness and Brooklynese accents, our southern slowness and western straightforwardness—but in another sense we are one. To the man we are now devoted to the profession of optometry and guardianship of vision, mankind's most precious faculty. As Dr. Ralph Barstow so ably wrote: "Next to Life itself, God's most gracious gift is sight, and to the services of this great gift of sight, we optometrists sincerely and faithfully dedicate our ministry."

A few short weeks, an exchange of solemn, personal greetings with our country's President and the vast majority of our class will have

*An abridgment of the material presented at the commencement exercises, Pennsylvania State College of Optometry, October 21, 1943. Submitted on November 4, 1943 for publication in the January, 1944, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†President of the graduating class of Fall, 1943, Pennsylvania State College of Optometry.

joined the ranks of the armed services. Many who as freshmen launched their optometric careers with us have already been in uniform for periods up to two-and-a-half years. Tonight they are to be found carrying out assignments in the most remote regions of this earth. One amongst them, Lieutenant Samuel Levitt, has made the supreme sacrifice for home and country. He will never sit on this rostrum as we do tonight eagerly anticipating the call of his name and the presentation of his diploma. In his memory, our class has established the Samuel N. Levitt Award to be presented at each Commencement exercise to that member of the graduating class who will have submitted the most outstanding thesis on a subject for original research in optometry. Even in instituting this prize it is vividly evident to us how woefully inadequate is any commemoration we may establish for those who have died for their and our country.

It has been the privilege of our classmates in arms to serve the United States in its moment of dire need. It has been our privilege to complete our training so that we may more ably serve in the future. As we receive our diplomas, documentary proofs of a goal attained, we cannot help but recall those who laid aside their books to answer our country's summons. After this world conflagration has been extinguished, God willing, they and we shall return—they to their optometric education, we to our private practices. To them we make a pledge, a pledge we will fulfill, a pledge that they on their graduation night shall enter a better optometry made so by our efforts.

Ours is a young profession and as such it has suffered at times. Commercialism in our ranks and the opposition of the medical profession have proved to be our most trying problems. Although blatant commercialists have distorted the public's conception of optometry, although the medical profession as a unit has been either not informed enough or not just enough to perceive our fitness and skill, our rate of growth has exceeded that of any comparable profession.

Now we have emerged from our infancy. Appreciation of our attainments and capabilities is increasing—inevitably, inexorably increasing. Whereas, we failed to secure even an iota of recognition during the last war, our history in this conflict has been one of steady progress. We now possess on the continually augmented positive side of the ledger: a limited number of Navy commissions; draft deferments for our seniors, juniors and sophomores as well as for practitioners deemed essential to the health of their communities; several commissions for specialized work in the Coast Artillery; and an occupational status in the Army.

Nevertheless optometry's role in the Army has not been a totally happy one—it would be hypocritical to claim otherwise. That is why it is to our credit that we have so wholeheartedly subjugated ourselves and our profession to the prime concern—victory in this, the greatest conflict of all time. Properly optometrists have been entrusted with the most vital task of administering to and preparing the eyes of our Army for combat duty. Yet we remain uncommissioned and unranked. Unfortunately the full extent of optometrical contributions and the superiority of optometrical methods have not penetrated into official reports because of prejudices prevalent among the powers-that-be. Yet innumerable individual medical officers, cognizant of our true worth, have admitted the injustice of our status.

But the triumph will eventually be ours, for optometry is on a long, but inevitable, uphill climb, and it is the stout determination of this graduating class to aid that climb by disseminating the ethical, theoretical and practical dogma instilled in us by our alma mater.

We of the Class of Fall 1943 have not traveled our path unaided. We are eternally obligated to those whose firm hands have guided us if we puzzled, supported us if we faltered. Debts such as those we owe our benefactors can never be repaid by material means. We only pray that in the future we shall in some small fraction be able to justify the patient understanding with which they have guided us and the unswerving trust that they have placed in us. Tonight we can but acknowledge the existence of these overwhelming obligations and our heartfelt gratitude for them. Thank you, Dean Fitch, our guiding light, for skillfully and staunchly steering our alma mater and the lofty ideals it symbolizes through an era of hardship; thank you, our distinguished faculty, whom it is our most zealous ambition to emulate—yours has been the multiple role of scholars, teachers, practitioners and friends; thank you, our parents, who have so resolutely nurtured us with both moral encouragement and material support. Our careers and our accomplishments—humble as they may be—will be a product of your endeavors, our Dean, our faculty, our parents, and to you are rightfully dedicated. We shall not betray your trust.

And finally, to you, my classmates, I bid a fond farewell and offer sincere thanks for the honor you have bestowed upon me. To each of you, Godspeed, happiness and success in our profession, optometry.

ANNOUNCEMENTS

NATIONAL SURVEY OF OPTOMETRISTS

Certain basic information as to the distribution of optometrists will become available as the result of a survey now being made on a nation wide scale by the Bausch and Lomb Optical Company at the request of the American Optometric Association. Following the survey the data gathered will be reviewed by Dr. Glenn Moore of Chicago, Director of the Office of Organizational Advancement, Professional Advancement Program of the A.O.A.

According to Dr. H. Ward Ewalt, Jr., "the Officers of the American Optometric Association, in their contacts with governmental agencies in Washington, such as Selective Service, the armed forces, the United States Public Health Service and others, are constantly embarrassed by questions such as: 'How many practicing optometrists are there?' 'How many towns of 5,000 population and less have the services of an optometrist?' 'What is the average age of practitioners?' etc. In the past they have been able to give only a rough estimate, because no one knows the answers.

"The job of personally interviewing more than 17,000 licensed optometrists is a large one for any organization to undertake. Through the generous cooperation of Bausch and Lomb it is going to be possible to do this job. All of the information that you give about your practice will be held confidential. Only statistics, averaged from the combined information, will be published.

"One of the big advantages which optometry has to offer as a health profession is the widespread distribution of its practitioners. We assert, and with a great deal of justice, that we are advantageously distributed to assist in any program of visual care. But—we cannot supply the actual figures or statstics which say in cold words that we have a certain number of optometrists in towns of 10,000, or in cities of 500,000.

"Another factor which makes for widespread optometric service is the large number of optometrists who have branch offices in outlying districts. But again, we have no way of knowing how many towns are covered until we have the information from the survey.

"The Office of Public Relations urges the full cooperation of every optometrist in the survey which is starting in the state of Wisconsin and

will be extended to every state in the Union. To repeat, the information is vitally necessary; it will be held in confidence and used only in the form of compiled statistics."

MONOGRAPHS ON READING READINESS BY EMMETT A. BETTS

Optometrists will be interested in learning that they may now secure two new monographs dealing with reading readiness as written by Emmett A. Betts, Ph.D.

Betts has long been active in optometric circles and is Director of the Reading Clinic and Research Professor at the School of Education, Pennsylvania State College.

His new monographs which are now available are (1) FACTORS IN READINESS FOR READING, reprinted from EDUCATIONAL ADMINISTRATION AND SUPERVISION, 32 pages, 1943, and (2) VISUAL READINESS FOR READING, reprinted from VISUAL DIGEST, 38 pages, 1943.

Optometrists wishing to secure both of these reprints should send $1 to the Reading Clinic, Pennsylvania State College, State College, Pennsylvania. A. V. F.

OPTOMETRY AND A PROGRAM OF REHABILITATION

The Public Health Bureau and Office of Public Relations of the American Optometric Association, under the direction of Dr. H. Ward Ewalt, Jr., has issued a report covering the first two months' operation of the office in its new home in Pittsburgh. Among the projects on which the Office has been working, is a student procurement brochure, "Planning Your Professional Career," suitable for distribution to high school and college students. This monograph is now being distributed.

According to Ewalt plans are being made by all federal agencies for taking care of the needs of the returning soldier. He says, "Optometry must have a place in any program of this sort."

Letters have been mailed to the State Adjutants of the Veterans of Foreign Wars, the American Legion, and the State Rehabilitation Directors of the Veterans Bureau, pointing out the contribution optometry can offer in visual rehabilitation of injured men, and as a profession for men eligible for government paid schooling. Optometrists having per-

sonal contacts with heads of veterans' organizations should, he claims, emphasize that it is in the common interest that no such contribution be overlooked in postwar planning. Ewalt requests optometrists who are Legion members to call attention to the need for such cooperation.

BOOK NOTICES AND REVIEWS

Books received are acknowledged by notices in this department. Special selections will be made for more extensive review in the interest of our readers as space permits.

THEORY AND PRACTICE OF ANALYTICAL REFRACTION AND ORTHOPTICS. Israel Dvorine, O.D., F.A.A.O. Second Edition, published by the Waverly Press, Baltimore, Md., 149 pages, Cloth, $3.50, 1943.

The second edition of Analytical Refraction and Orthoptics is now off the press. It is a book that deserves wide reading among all refractionists. The author refuses to accept some of the older theories and presents to his readers his own particular thinking and that of the Optometric Extension Program as these deal with the problems of eye care.

There are three groups of optometrists in America today. First, a large block of refractionists who practice in what may be termed the orthodox manner and who in great part pay little attention to anything else. Second, a group of optometrists who yearly enroll in the Optometric Extension Program and who attend its meetings, but who do not use its technical material in actual practice. And third, a small militant band of optometrists who not only enroll in the Optometric Extension Program, but who also conduct their refractions in accordance with its tenets. Dvorine belongs in this third category, and of this group he is one of the most lucid and convincing.

Now all three groups should read this revised text. The orthodox refractionist should read Dvorine (1) because it will wake him up, (2) make him mad, (3) stimulate his thinking and (4) give him some idea at least of what it is that Dr. A. M. Skeffington has been talking about for all these many years.

The second group should buy and read the book because it will throw a good deal of light on a lot of material they receive at their Optometric Extension Program meetings that now seems obscure to many of them. Conditioned as this group are to the jargon used in the program they may even try putting into practice some of the techniques

they have been hearing about at the meetings. In the opinion of the reviewer, if Dvorine fails to sell group two this technical package, it just can't be sold.

The third small group should read the book because the author reviews in detail and with manifest understanding the precise techniques they have been using and he does so in such refreshing fashion that it will enable these men to become better teachers. A study of Dvorine will enable these men to present clearer explanations of their beliefs to other optometrists at their round-table sessions.

This second edition has an introduction by that well known educator and visual research specialist, Dr. E. A. Betts, who says, "A point of view is presented in this book that will challenge the attention of careful students in this field of vision." The book covers the following material. The optometric and medical methods of refraction: The theory of Analytical refraction: The 21 point refraction technique and how to make each test: A review of typical case reports and the formula that was prescribed: A discussion of cases that do not type: Orthoptics and the procedure to follow in reconditioning B and C type cases, and the correction of squint.

Dvorine is one of the outstanding members of the Academy. In revising this text he has again performed a real signal service for his profession. This new book dealing with ocular refraction is a real war-time contribution to our literature and science. CAREL C. KOCH.

ECONOMICS IN VISUAL EYE CARE. Published by the American Optical Company. Southbridge, Mass. 24 pages. 1943.

The American Optical Company announces publication of ECONOMICS IN VISUAL EYE CARE—which suggests to optometrists some essential methods of practicing in accordance with the highest ethics and the soundest economics of the profession. Copies of the book are now available for the profession and have been mailed to optometrists for study and consideration at the request of Dr. James A. Palmer, National Director of the Office of Ethics and Economics of the American Optometric Association's Professional Advancement Program, who believes the book will help further the program.

This new book is an important step in the development of the AMERICAN Plan because it not only graphically illustrates the insepara-

bility of the professional services rendered and the responsibilities assumed, but it also symbolizes the elements and services which enter into the determination of a professional fee. Furthermore, it provides a sound economic basis for the transition from "selling-glasses-as-a-commodity" to rendering professional services at a fee.

The authors state, "The book has a two-fold purpose. The first part of the book points out the errors of the past system of practice and its consequent damage to sound optometric economics. The latter part helps keep straight the proper evaluation and measurement of professional services and responsibility." In no case, throughout the book, has there been an attempt to measure, evaluate or state dollar values. Symbols have been used only to measure professional responsibility in terms of services rendered. Pages 16 to 22 are significant. Here are shown (1) symbolical methods of calculating fees for professional services in complete unified service; (2) in duplication services where an "extra pair of glasses" are required; (3) when the prescription goes to the ophthalmic dispenser; (4) when the glasses are professedly procured at wholesale; (5) when the patient's own frame is used; and (6) in replacements or repairs.

This monograph pictures the right and wrong way of facing most of the everyday economic problems arising in the practice of optometry and thus represents an answer to a pressing need. This handbook of optometric economics deserves study in order that its fundamental theories and practices may better be accepted by all optometrists.

T. O. B.

PUBLISHERS NOTICE—As a reader of this publication, you no doubt have noticed that your AMERICAN JOURNAL AND ARCHIVES OF THE ACADEMY magazine is lighter in weight than formerly. To cooperate fully in our war program of conservation of resources, this journal is now printed on 60-pound weight paper instead of the 80-pound paper formerly used. Plans for 1944, call for the usual 12 issues, each of 56 pages, plus cover. The Academy and the Publishers are glad to make this contribution to the Nation's War Effort.

ABSTRACTS

A department in which will appear abstracts of the literature of optometry, ophthalmology and applied optics. These will be classified according to the following list although contributions to all sections will not necessarily appear in each issue.

1. Ocular Refraction.
2. Physiological Optics and Color Vision.
3. Ocular Muscles.
4. Orthoptics and Reading.
5. Anatomy, Histology and Embryology.
6. Ocular and General Pathology.
7. Ophthalmic Lenses and Material.
8. Instruments.
9. Hygiene and Illumination.
10. Applied and Physical Optics.
11. Education, Sociology and Economics.
12. Miscellaneous.

6. OCULAR AND GENERAL PATHOLOGY

RIBOFLAVIN. M. Heinman, Archives of Ophthalmology, 1942, 28, 3, 493.

The clinical symptoms of ariboflavinosis are explained as manifestations of inactivity of the different functions of riboflavin. Diminished visual acuity is due to lack of riboflavin in the fovea centralis and its effect on the conveyor function. Dimness of vision is based on the lowered function of transformation and intensification. Photophobia is the manifestation of the reduction of the protective function. It is believed that the various functions of riboflavin affect the visual act only as far as the cones are concerned. Riboflavin and the cones form a functional unit.

L. P.

CHANGES IN OCULAR REFRACTION FROM SYSTEMIC CAUSES. L. W. Oaks, Eye, Ear, Nose and Throat Monthly, 1942, 21, 7, 213-217.

The author finds that changes in ocular refraction are due to the following systemic causes: Alkalosis, strict dietary change, toxemia of pregnancy, toxemia from arsphenamine therapy, toxemia from prontosil therapy, toxemia from acute exanthemata, early developing cataracts, arteriosclerosis, and, most common among written observations, diabetes mellitus. To these the writer has added toxemia of acute alcoholism. The suggestion is offered that alterations in ocular refraction from systemic causes may really arise from unrecognized disturbance by various toxins of the sympathetic-parasympathetic-endocrine balance, producing an allergic upset of the ocular mechanism and tissues. A. V. F.

LENS OPACITIES AND CILIARY GROWTHS. L. A. Swan, Optician (London), 1943, 106, 2743, 180.

The author points out the need for examining the periphery of the crystalline lens because it is by this means that growths in the posterior portion of the ciliary body can be detected. Early recognition is urged because these growths threaten life itself. When there is a growth in the ciliary body, focal illumination or even general inspection many reveal a congestion of the ciliary veins at the site of the growth. These congested veins will be seen through the conjunctiva. As the growth increases in size it will impede the ophthalmoscopic illumination which is used for the examination of the periphery of the crystalline lens. The growth will present a crescent-shaped shadow which can be easily mistaken for early peripheral cataract. For this reason, what may appear to be peripheral opacification of the lens must be subjected to close examination.

Because early cataract is opacification of the lens fibres, the opacities are rarely limited to a straight edge as they point to the lens nucleus. Such opacities are feathery and vary in density. Ciliary growths are not feathery and are opaque to transmitted light. Consideration of the density factor calls for an alteration in the ophthalmoscopic illumination. Lenticular opacities may appear entirely opaque with ordinary ophthalmoscopic illumination, but if the illumination is rendered parallel or convergent, the density will be seen to vary. No alteration of illumination will have a similar effect in a posterior ciliary growth.

G. L. DUP.

FUNDUS OCULI IN VASCULAR DISEASE. M. Cohen, Archives of Ophthalmology, 1943, 29, 1, 85.

The author points out that an ophthalmoscopic examination is an invaluable aid in the diagnosis and prognosis of hypertensive vascular disease, as it provides a visible guide to the condition of the general vasculature such as cannot be observed in any other organ or tissue of the body. Cohen also points out that a terminal phase of malignant hypertension is recognized by papilledema, or swelling of the disk with an elevation of 2 or more D., in contradistinction to optic neuritis, in which there is but a slight elevation of the disk and surrounding tissue.

He adds that the prognosis for life in hypertensive vascular disease depends mainly on the involvement of the vital organs and not on the ophthalmoscopic findings. T. O. B.

A CASE OF BILATERAL PTOSIS. Robert Luskin, Columbia Optometrist, 1943, 17, 66, 2.

The patient suffered from a complete paralysis of the external muscles of both eyes, with a complete bilateral ptosis. Instead of prescribing the usual wire type of ptosis crutch, the author devised a "shelf-type" in which the "shelf" was made of transparent plastic riveted on a metal plate that was soldered to the top of the eye wire of the spectacle frame. The author found the plastic to be comfortable and well adapted to fitting against the supra-orbital ridge. C. C. K.

ESSENTIALS OF FIRST AID AND LATER MANAGMENT IN INDUSTRIAL INJURIES TO THE EYE. S. Walker, Jr., and H. L. Auten, Journal of the American Medical Association, 1941, 116, 1356.

In cases of industrial injury to the eye the authors present the following five points of first aid care: 1. It is important to determine the visual acuity at the time of the first visit, and in the injured eye first. 2. Injuries of the eye which appear trivial are often potentially dangerous, especially in the presence of focal infection. 3. The use of a mydriatic after removal from the cornea of foreign bodies or any injury to the cornea affords the patient comfort and expedites healing. 4. Bandages and patches tend to produce infection by damming up secretions and should not be used. 5. It is unwise for the general physician or surgeon to take chances. He should pass the responsibility on to the local oculist if there is doubt about any factor in a case. C. C. K.

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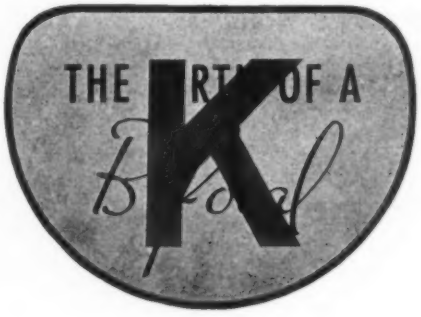

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About one-half of the space is devoted to technical articles, and the remaining half is given over to special departments, editorials, abstracts and book reviews, in large part original.

The papers and reports are original and are accepted only with the understanding that they are to be published in this journal exclusively.

The editors of the American Journal of Optometry and Archives of American Academy of Optometry beg to offer the following suggestions to authors who propose to favor them with the publication of their contributions:

I. Write on one side of the paper. Double-spaced, typewritten MS. is preferred.

II. Words to be printed in *italics* should be underscored once, in SMALL CAPS twice, and in LARGE CAPITALS three times. **Antique type** when called for should be so marked.

III. Be sure that the title of your paper indicates its contents. Should the subject be a general one, for instance, Case Reports, it would be well to mention the subject of each special report—for instance: Case One. Progressive Myopia with Exophoria. Case 2. Divergent Squint with Amblyopia. These special titles will appear in the table of contents of each number.

IV. Illustrations should be carefully drawn with India Ink on separate sheets.

V. When authors receive proofs for revision, they should correct and return these without delay. We beg, however, to remind our contributors that changes in the manuscript necessitates resetting, this causing much additional expense, so we ask that alterations be limited to what is of essential importance.

VI. Because of the added cost, we have discontinued the giving of gratuitous reprints to our authors, but we will supply them with these at the cost of press work and paper where so desired. The following tables of charges will apply for the year 1944.

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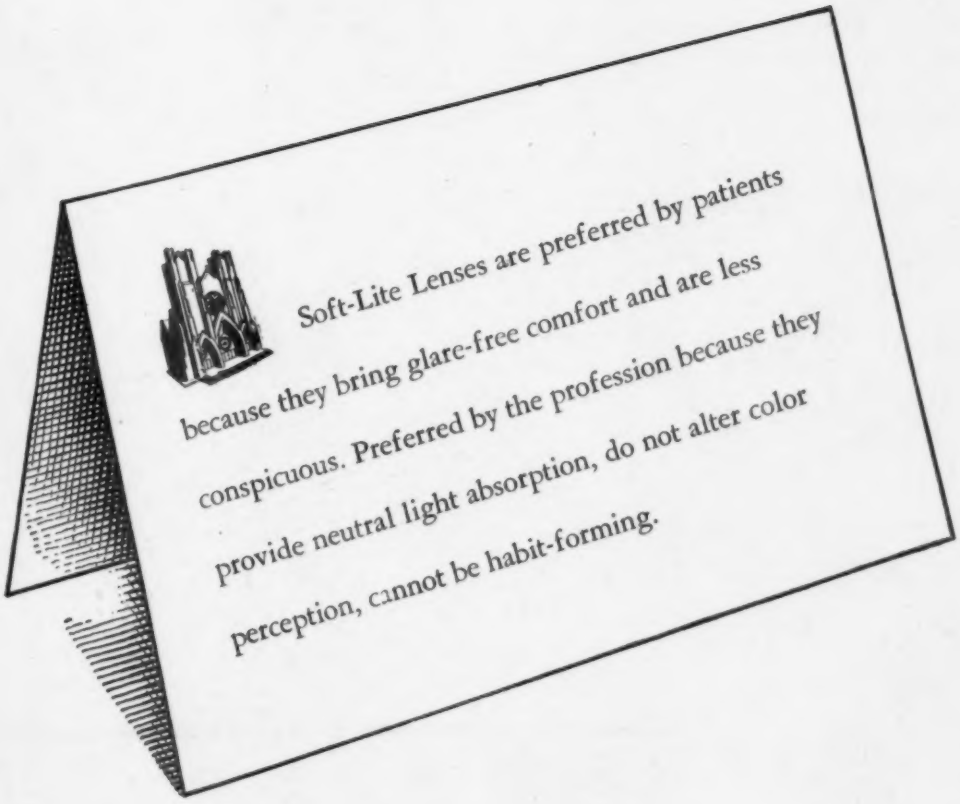
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